SELF-TEST

A. Multiple Choice:

1. For the following system at equilibrium

$$C\,(s) + H_2O\,(g) \rightleftharpoons CO\,(g) + H_2\,(g)$$

increasing the volume of the container

a. forms more C (s).
b. forms more CO (g) and H_2 (g).
c. has no effect on equilibrium.

2. For the reaction

$$A\,(g) + B\,(g) \rightarrow 2\,C\,(g)$$

K is 9.0 at 35°C. The original partial pressures of the species are: $P_A = 0.2$ atm, $P_B = 0.4$ atm, and $P_C = 0.15$ atm. Which of the following statements is true?

a. The reaction will move to the left to achieve equilibrium.
b. The reaction will move to the right to achieve equilibrium.
c. The mixture of gases is at equilibrium.
d. The mixture cannot achieve equilibrium unless more gas is added.

3. The exothermic reaction

$$X\,(g) + Y\,(g) \rightarrow 2\,Z\,(g)$$

reaches equilibrium at 200°C. How many of the following statements are true?

— If the mixture is transferred to a reaction flask of twice the volume, the amount of products and reactants will not change.
— Addition of an appropriate catalyst will result in the formation of a greater amount of Z (g).
— Lowering the temperature to 100°C will increase the amount of Z (g).
— Addition of helium will have little or no effect on the amount of Z (g) obtained.

a. 0 **b.** 1 **c.** 2 **d.** 3 **e.** 4

4. How is the following equilibrium shifted by cooling?

$$CuS\,(s) + H_2\,(g) \rightleftharpoons H_2S\,(g) + Cu\,(s) \qquad \Delta H = 28\,kJ$$

a. Hydrogen sulfide gas is formed.
b. Hydrogen sulfide gas is consumed.
c. There is no change.

5. Three chemical systems are each in equilibrium.

(1) $2\,CO\,(g) + O_2\,(g) \rightleftharpoons 2\,CO_2\,(g)$
(2) $H_2\,(g) + Cl_2\,(g) \rightleftharpoons 2\,HCl\,(g)$
(3) $2\,HI\,(g) \rightleftharpoons H_2\,(g) + I_2\,(s)$

The pressure on each of these systems is increased so that the volume decreases from 20 L to 10 L. The equilibrium shift is correctly represented as

a.	(1)	→	(2)	→	(3) no change
b.	(1)	no change	(2)	←	(3) ←
c.	(1)	→	(2)	no change	(3) →
d.	(1)	←	(2)	→	(3) no change
e.	(1)	→	(2)	no change	(3) no change

6. The gaseous reaction

$$N_2\,(g) \rightleftharpoons 2\,N\,(g) \qquad \Delta H = +941\ kJ$$

is in equilibrium at 1200 K. Which of the following operations will increase the value of the equilibrium constant, K?

(1) Addition of nitrogen (N_2) gas
(2) Increasing the temperature
(3) Increasing the pressure

a. (1) **b.** (2),(3) **c.** (1),(3) **d.** (2) **e.** (3) **e.** none of those

7. For the reaction

$$A\,(g) + 2\,B\,(g) \rightarrow 3\,C\,(g)$$

K is 1.0 at 500°C. The original partial pressures of the species at 500°C are: $P_A = P_B = P_C = 0.2$ atm. Which of the following statements is true?

a. The partial pressure of A will increase as equilibrium is reached.
b. The partial pressure of B will increase as equilibrium is reached.
c. The partial pressure of C will increase as equilibrium is reached.
d. The system is already at equilibrium.
e. None of the above statements represents reality.

8. At 25°C

$$2\,NO\,(g) \rightleftharpoons N_2\,(g) + O_2\,(g) \qquad K = 1 \times 10^{30}$$
$$2\,H_2O\,(g) \rightleftharpoons 2\,H_2\,(g) + O_2\,(g) \qquad K = 5 \times 10^{-82}$$
$$2\,CO\,(g) + O_2\,(g) \rightleftharpoons 2\,CO_2\,(g) \qquad K = 2.5 \times 10^{91}$$

The compound most likely to dissociate and give O_2 (g) at 25°C is

a. NO **b.** H_2O **c.** CO_2 **d.** CO

9. What is the equilibrium expression for the following reaction?

$$2\,SO_2\,(g) + O_2\,(g) \rightleftharpoons 2\,SO_3\,(g)$$

a. $\dfrac{(P_{SO_3})^2}{(P_{SO_2})^2\,(P_{O_2})}$ **b.** $\dfrac{(P_{SO_3})^2}{(P_{SO_2})^2 + (P_{O_2})}$ **c.** $\dfrac{2\,(P_{SO_3})}{2\,(P_{SO_2})\,(P_{O_2})}$

d. $\dfrac{(P_{SO_2})^2\,(P_{O_2})}{(P_{SO_3})^2}$ **e.** $\dfrac{4\,(P_{SO_3})^2}{(P_{SO_2})^2\,(P_{O_2})}$

10. For the reaction

$$CO\,(g) + H_2O\,(g) \rightleftharpoons CO_2\,(g) + H_2\,(g)$$

K is 1.00 at about 1100 K. Which one of the following statements must always be true concerning this reaction at equilibrium?

a. $P_{CO} = P_{H_2O} = P_{CO_2} = P_{H_2}$
b. $P_{CO} \times P_{H_2O} = P_{CO_2} \times P_{H_2}$
c. $P_{CO} = P_{H_2O}$ and $P_{CO_2} = P_{H_2}$
d. $P_{CO} \times P_{H_2O} = P_{CO_2} \times P_{H_2} = 1.00$
e. All of the above are true.

B. Circle the correct answer:

Consider the system

$$N_2\,(g) + 3\,H_2\,(g) \rightleftharpoons 2\,NH_3\,(g) \qquad \Delta H = -92.2\ kJ$$

Show the effect on the partial pressure of H_2 and on the numerical value of K by circling the letters D for a decrease, I for an increase and NC for no change.

	P_{H_2}			K		
1. adding NH_3	D	I	NC	D	I	NC
2. doubling the volume	D	I	NC	D	I	NC
3. increasing T	D	I	NC	D	I	NC
4. adding Ar (g)	D	I	NC	D	I	NC
5. adding N_2 (g)	D	I	NC	D	I	NC

C. Fill in the blanks:

The following questions are about the following hypothetical reaction:

$$2\,R\,(g) + S\,(\ell) \rightleftharpoons T\,(g) + 2\,U\,(g) \qquad K = 1$$

_____ **1.** What is the partial pressure of R at equilibrium if the equilibrium partial pressure of T is 1 atm and that of U is 2 atm.

_____ **2.** In which direction will the reaction proceed ($\rightarrow$, $\leftarrow$, or no change) if the volume of S is doubled?

_____ **3.** It is determined that K increases when the temperature is increased. What is the sign of $\Delta H°$ for the reaction?

_____ **4.** In which direction will the reaction proceed if Q = 2? ($\rightarrow$, $\leftarrow$, can't tell)

_____ **5.** What is K (equilibrium constant) at the same temperature if the pressure of R is doubled from 1 atm to 2 atm?

D. Problems:

Consider the hypothetical reaction

$$A\,(g) + B\,(g) \rightleftharpoons 2\,C\,(g) \qquad \Delta H < 0$$

1. Write the equilibrium expression for the reaction.

2. Calculate K at a certain temperature if $P_A = 0.250$ atm, $P_B = 0.135$ atm, and $P_C = 0.500$ atm.

3. For another temperature, calculate K if we start with a 5.00-liter flask in which $P_A = 0.300$ atm and $P_B = 0.750$ atm. At equilibrium, 25.0% of A has been used up.

4. If K for the reaction at 100°C is 50.0, and we start with a 1.00-L flask where: $P_A = P_B = 0.250$ atm, and $P_C = 0.500$ atm

a. Determine the direction of the reaction.

b. Calculate the partial pressures at equilibrium of A, B, and C at 100°C.

c. After equilibrium has been reached, the pressure of C is temporarily increased to 1.500 atm. Calculate the partial pressures of A, B, and C after equilibrium has been reestablished.

5. State in which direction the equilibrium will shift to relieve the following stresses on the system.
   a. Increase T.

   b. Increase V.

   c. Add Ar.

   d. Increase the concentration of A.

6. Recall that K is 50.0 at 100°C. At 23°C, K is 137. What is $\Delta H°$ for the forward reaction?

ANSWERS
Exercises:

(E1) $K = \dfrac{(P_{NO})^4 (P_{H_2O})^6}{(P_{NH_3})^4 (P_{O_2})^5}$

(E2) $K = (P_{NO_2})^2 (P_{O_2})^{\frac{1}{2}}$

(E3) 2.0×10^1

(E4) $NH_4Cl\ (s) \rightleftharpoons NH_3\ (g) + HCl\ (g)$; $K = (P_{NH_3})(P_{HCl})$; $K = 0.544$

(E5) 0.953

(E6) 0.522

(E7) left to right ($\rightarrow$)

(E8) 2.1 mg

(E9) $P_{H_2} = P_{CO_2} = 0.13$ atm; $P_{CO} = 0.12$ atm; $P_{H_2O} = 0.22$ atm

(E10) **a.** $\rightarrow$ **b.** $\leftarrow$ **c.** $\leftarrow$ **d.** $\rightarrow$ **e.** $\rightarrow$

(E11) $P_{H_2} = 0.619$ atm; $P_{CO_2} = 0.219$ atm; $P_{CO} = 0.281$ atm; $P_{H_2O} = 0.481$ atm

(E12) 953 K

Self-Test

A. Multiple Choice:

1. b **2.** b **3.** d **4.** b **5.** c
6. d **7.** d **8.** a **9.** a **10.** b

B. Circle the correct answer:

1. I NC **2.** I NC **3.** I D **4.** NC NC **5.** D NC

C. Fill in the blanks:

1. 2 atm **2.** no change **3.** + **4.** ← **5.** 1

D. Problems:

1. $K = \dfrac{(P_C)^2}{(P_A)(P_B)}$

2. 7.41

3. 0.148

4a. Reaction goes to the right

4b. $P_A = P_B = 0.110$ atm; $P_C = 0.780$ atm

4c. $P_A = P_B = 0.190$ atm; $P_C = 1.341$ atm

5a. ← **b.** no change **c.** no change **d.** →

6. –12.0 kJ